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Sustainable Household Energy for Addis Ababa, Ethiopia

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Abstract

This paper presents the household energy consumption trends and alternatives for Addis Ababa, Ethiopia. The study shows that, during the decade that the study was conducted, household energy consumption per capita increased by 17% from 6GJ. Traditional fuels accounted for about 80% of the consumption. Household energy expenditure per person tripled from $10 to $30. The energy consumption trend is highly correlated with fuel price; in 1995, charcoal was the most expensive fuel (~$7 per GJ), followed by LPG and electricity (~$5 per GJ). Kerosene was sold at about half the price of charcoal, while fuelwood was the least expensive (~$1 per GJ). In 2005, charcoal prices increased by about 20%, while fuelwood price declined by more than 10%. The price of electricity doubled while that of kerosene tripled and LPG quadrupled. Despite the rise in price, electricity consumption shot up by a factor of twenty, and kerosene declined by half. During the decade, traditional fuel use increased by 10% while modern energy use increased by 50%. The paper also considers the potential explanations and policy implications of the trends in the data.

Keywords: Ethiopia, household energy, energy consumption, fuels, fuelwood.

1. Introduction

According to the World Bank, in 2011, Ethiopia was categorized as a low-income developing country with a GDP per capita of $320 and an average growth rate of 8% over the preceding decade (World Bank, 2011). In the same year, the country's energy use per capita was about 16 gigajoules (GJ) and the primary energy consumption was 1.3 exajoules (EJ). Electricity, produced almost entirely from hydropower, accounted for 1%, oil for 7%, and traditional fuel for the remaining 92%. Charcoal and fuelwood are the principal traditional fuels. In the last fifty years, charcoal production increased from a million tonnes to more than three million tonnes per annum. During the same period, fuelwood consumption also increased from forty million to one hundred million cubic meters per annum. The production of charcoal and fuelwood are the primary drivers of deforestation and subsequent land degradation due to extensive agriculture. Oil's share of the country's total imports varied between 15% and 25% but consumed up to 70% of the export earnings, though it accounts for 7% of the country's energy use. In 2008, according to the National Bank of Ethiopia, oil imports exceeded total exports by 50% during the second quarter (NBE, 2008).

Perhaps most important, however, is the relationship between household energy use in Ethiopia and issues of environmental degradation–both at the local and the global level–and the issue of energy security. To properly inform future energy policies, then, it is necessary to understand the recent trends of energy production and use in Ethiopia, as represented by the energy data for Addis Ababa.

Addis Ababa, the capital city of Ethiopia, is located close to the equator at an altitude of roughly twenty-three hundred meters above sea level, where it enjoys a mild climate. The average monthly temperature based on eight years of weather readings varies from fifteen degrees Celsius in the month of December to eighteen degrees in May (Climate Zone, 2004). In 1887, Menelik II founded Addis Ababa, which means "*new flower*," as his capital. At the time, the city and its surrounding mountains were covered with natural but slow growing *Juniperus*, *Podocarpus, Ole* forest. With an increasing population, the demand for fuelwood and construction by the inhabitants resulted in heavy deforestation. Subsequently, fuelwood shortages threatened the very existence of the city and, as a potential solution, Menelik II in 1895 introduced eucalyptus from Australia into the country (Pankurst, 1968) (Horvath R. , 1968). The introduction was a success, and at the turn of the twentieth century, the practice of growing eucalyptus for fuel expanded into the area surrounding the city. Hence, if it were not for the dramatic success of eucalyptus, Addis Ababa would not have come to exist as the Emperor would have been forced to move elsewhere to look for fuelwood. In the 1930s, the size of eucalyptus plantation was around five thousand hectares (Giordano, 1938), while in the 1950s it expanded to fifteen thousand hectares and later in 1960's to about twenty-five thousand hectares (Horvath R. J., 1968).

In the 1980's, Ethiopia's population increased by 60% as compared to the 1960's, which resulted in 70% and 50% increases in the consumption of charcoal and fuelwood, respectively (World Bank, 2011). In order to meet the growing demand for wood in a sustainable way, five million hectares of well-managed indigenous forest or one million hectares of fast-growing eucalyptus plantations were needed (Pohjonen V. , 1989). At the time, such forest resources did not exist. The remaining forest cover was about three million hectares, most of which was inaccessible. The established plantations at the time were slightly more than three-hundred thousand hectares. Consequently, the annual harvest continued to exceed annual growth, which led to a serious decimation of forests resources at an alarming rate of one-hundred thousand to two-hundred thousand hectares per year (Bowen, 1985). This in turn caused an acute energy crisis that forced the people to use cow dung and crop residues for energy. Based on a survey conducted at the time, fuelwood production accounted for 38% percent of the total energy production, while charcoal accounted for 5%, crop residue for 24% percent, and cow dung for 23% (Pohjonen & Pukkala, 1988). In response to the imminent energy crisis caused by this depletion of forest resources, the government enacted a reforestation policy in 1980 and initiated reforestation projects with the goal of planting about three million hectares of land primarily for fuelwood (Pohjonen V. , 1989). As part of this scheme, the Addis Ababa fuelwood plantation project was established in 1985 with funding from the

African Development Bank. The objective was to establish an additional fifteen thousand hectares of plantation at the outskirts of Addis Ababa; the project managed to implement 85% percent of the target. Two years later, the Addis-Bah plantation project was initiated with funding from the World Bank to upgrade thirteen thousand hectares of plantation and establish an additional seven thousand hectares of new peri-urban plantation in addition to the thirty-three thousand hectares available at the time. These measures, in addition to averting the anticipated energy crisis in Addis Ababa, managed to make fuelwood more affordable, especially to the poor.

Cooking, especially that of the traditional bread *injera*, accounts for 85% of household energy use in Addis. 6% is used to heat water and space, and an average of just 1% is used for lighting (Woody Biomass Inventory and Strategic Planning Project, 2004).

The results presented in this paper are based on the data obtained from the Central Statistics Agency for the years 1995 and 2005, which reveal fuelwood as the most predominant and least expensive fuel source for household energy in Addis Ababa. In 1995, it met nearly 80% of household energy use, but in 2005 fuelwood consumption per person declined by 22%, despite a 13% drop in price. Charcoal, which is eight to ten times more expensive than fuelwood and is comparable to kerosene, is consequently being consumed much less. During the decade the survey covered, consumption of traditional fuels, which include dung and sawdust, has increased. The relative price inflation of modern energy sources such as electricity has ranged from 120% to 320%. As a result, kerosene and LPG (liquefied petroleum gas) consumption declined considerably. Surprisingly, however, electricity consumption increased dramatically. In 2003, the government established a stabilization fund to ease the high price of kerosene. Initially, the kerosene subsidy was about 2.3 million US$, whereas it exceeded sixty million US$ in the third quarter of 2008, forcing the government to terminate the program before the year ended (Ministry of Water and Energy of Ethiopia, 2011). Currently, despite a rise in price, fuelwood is still the most affordable fuel, especially for the poor. However, consumption is dropping since it does not fit well into the urban lifestyle. The city is currently planning to build more than three-hundred thousand apartment units, a plan that is going extremely well. The use of fuelwood in such apartment complexes is necessarily very limited. Therefore, fuelwood consumption in most households will presumably phase out over time. Charcoal production is limited simply because there is insufficient wood to produce enough to meet the demand. Predictably, this shortage of charcoal is driving the price higher, closer to kerosene, which results in a subsequent drop in consumption. LPG is very expensive, and only the middle and upper class can afford it. As a result, its consumption is declining as well. Soon after the kerosene subsidy was terminated, the price of electricity was slashed in half to stabilize the rising fuel cost. Currently, electricity produced through local hydropower is the only truly sustainable as well as affordable source of household energy in Addis Ababa.

In 2010, as compared to 2005, due to the devaluation of the local currency, household fuel price have increased significantly. Charcoal and LPG have doubled in price, whereas the price of fuelwood has tripled, and that of kerosene quadrupled. Though the price of electricity has been reduced by half, it still cannot satisfy the growing energy demand unless other alternative fuels are developed alongside it.

Ethiopia has twenty-five billion cubic meters of proven yet unexploited natural gas reserves, one of the largest reserves in Sub-Sahara Africa (CIA, 2011). The potential for oil production from inedible plants such as jathropa, castor, and rapeseed, which can be grown on marginal lands not suitable for agriculture, is also high (Kinfu, Asfaw, & Asfaw, 2009). Oil derived from moringa seeds, which can be found in abundance in the southern part of Ethiopia, could be used as fuel for households as well as for transportation (Ejigu, Asfaw, Asfaw, & Licence, 2009). If these renewable and non-renewable fuel sources are developed, they could supply households with sustainable energy by replacing the current traditional and imported fuels, which contribute to environmental problems. Such locally-produced sustainable fuels could control fuel price inflation, reduce deforestation and land degradation associated with traditional fuel use, and eliminate indoor pollution caused by burning biomass and kerosene.

2. Methods and Data

The 1995 census (CSA, 1995) reported that the population of Addis Ababa was about two million. In 2005, it reached about two and a half million (CSA, 2005). According to the census, the mean household size was about six and five in 1995 and 2005, respectively. In 1995, 46% of the residents were female while in 2005 the ratio remained the same. The standard deviations for the 1995 and 2005 surveys were 2.76 and 2.63, respectively.

The data provided in this study were derived from the secondary raw electronic database of Addis Ababa, surveyed by CSA in 1995(CSA, 1995), and 2005 (CSA, 2005). The survey categorized households into deciles based on total expenditures such as fuel. The average fuel consumption data is converted into primary and end-use per capita energy consumption, shown in Table 1, using the energy values of the primary fuels and the efficiency of the stoves commonly used(Dutt & Ravindranath, 1993). The fuel price (US$ per gigajoules) shown in Table 2 is calculated based on the fuel retail price and exchange rate provided by the National Bank of Ethiopia (National Bank of Ethiopia, 2008). The household energy expenditure per capita shown in Table 3 is calculated using the energy consumption per capita from Table 1 and the fuel price provided in Table 2.

Year	E (GJ)	Charcoal	Fuelwood	Sawdust	Dung	Electricity	LPG	Kerosene	Total
1995	Primary	0.186	4.396	0.238	0.034	0.041	0.519	0.530	5.943
	Enduse	0.037	0.703	0.071	0.004	0.029	0.312	0.212	1.368
2005	Primary	0.172	3.449	1.359	0.311	0.980	0.418	0.288	6.976
	Enduse	0.034	0.552	0.408	0.034	0.696	0.251	0.115	2.090
$\Delta E/E$		-7%	-22%	471%	823%	2293%	-19%	-46%	17%

Table 1: Primary and end-use household fuel consumption per capita of Addis Ababa for the year 1995 and 2005

	Fuel Price US$/GJ						
Year	Charcoal	Fuelwood	Sawdust	Dung	Electricity	LPG	Kerosene
1995	7.27	0.93	0.93	4.65	5.81	5.87	3.32
2005	8.48	0.81	0.81	6.45	12.8	24.57	9.87
2010	9.88	1.25	1.25	15.41	4.59	28.76	18.49

Table 2: Fuel price US$ per gigajoules

	Traditional($)					Modern($)				
	Charcoal	Fuelwood	Sawdust	Dung	Traditional	Electricity	LPG	Kerosene	Modern	Total
1995	1.35	4.09	0.22	0.16	5.82	0.24	3.05	1.76	5.05	10.86
2005	1.46	2.78	1.10	2.01	7.34	12.54	10.28	2.84	25.66	33.01
$\Delta\$/\$$	8%	-32%	395%	1180%	26%	5169%	237%	61%	408%	204%

Table 3: Household energy expenditure per capita

3. Results and Discussion

3.1 Household energy consumption trend

The household fuels of Addis Ababa can be categorized as traditional and modern. Charcoal, fuelwood, sawdust, and dung make up the traditional fuels while kerosene, Liquid Petroleum Gas (LPG) and electricity from hydropower make up the modern fuels. In 1995, the per capita household energy consumption of Addis Ababa was about 6 GJ; traditional fuel shared 82% of the primary energy. In 2005, household energy consumption per capita increased by 17% (about 7 GJ); traditional fuel accounted for 76% of this consumption. Relative to 1995, traditional fuel consumption increased by 9% while the rise in modern fuel use was 55%.

A closer look at traditional fuel consumption trends reveals that in 1995, fuelwood accounted for 74%, followed by sawdust and charcoal, which account for 4% and 3% of the share, respectively. Dung had the lowest share (1%). In 2005, fuelwood consumption declined by 22%, but it continued to supply 56% of the household fuel. The decline in fuelwood consumption was somehow compensated with a rise in sawdust and dung consumption, which exhibited increases of 473% and 832%, respectively, together constituting 5% of the total consumption, higher than that of charcoal (3%). Charcoal consumption declined by 7% during the decade, but the net traditional fuel consumption increased by 6%.

The 19% decline in LPG consumption in 2005 relative to 1995 is very likely due to the quadrupling in price of LPG. During this time, despite the subsidy on kerosene, its price tripled, which could be the primary reason why consumption declined by almost half. Similarly, the 7% drop in charcoal consumption may be attributed to the 18% rise in charcoal price. With regard to dung, however, consumption increased nine fold while the price rose by 40%. Since dung is mainly utilized in the peri-urban areas, there could be factors other than price responsible for this trend. With regard to electricity, consumption increased by a factor of 23 while the price doubled. If the stove efficiency is taken into consideration, electricity is found to be cheaper than kerosene, LPG, and charcoal.

With regards to modern fuel consumption, in 1995, LPG and kerosene each met 9% of household energy needs, while electricity consumption was a marginal 1%. In 2005, however, electricity use increased by an astonishing 2293%. On the other hand, kerosene and LPG consumptions dropped by 46% and 19%, respectively. Overall modern fuel consumption doubled primarily due to the dramatic rise in electricity consumption.

Looking at the energy price can shine light on the observed consumption trend. In 2005, compared to 1995, the price of electricity doubled, while that of kerosene tripled and LPG quadrupled. The price of charcoal and dung increased by 17% and 39%, respectively, while the price of fuelwood and sawdust decreased by 13%. In 1995, compared to the price of electricity, LPG was close in price, while charcoal was 25% more expensive and kerosene half the price. On the other hand, electricity was six times more expensive than fuelwood and sawdust.

In Table 4, the primary energy needed from the commonly used modern fuels including charcoal to produce a gigajoule of end-use energy is given. Based on the 2005 energy price (Table 2), the apparent fuel cost is provided in the same table. The result shows that electricity is the cheapest modern fuel and that it is also cheaper than charcoal. It also requires the least amount of primary energy. This probably explains the dramatic rise in electricity consumption despite its doubling in price.

Relative to	1995	2005	Electricity		
Fuel type	2005	2010	1995	2005	2010
Electricity	120%	-64%	0%	0%	0%
LPG	319%	17%	1%	92%	527%
Kerosene	197%	87%	-43%	-23%	303%
Charcoal	17%	16%	25%	-34%	115%

Table 4: Relative fuel price

In 1995, the household energy expenditure per person per year was about US$10 distributed almost evenly between traditional (54%) and modern fuel (46%). In 2005, the total expenditure tripled; expenditure on modern fuel increased fivefold, while spending on traditional fuel rose by about 25%.

3.2 Alternative Fuels

In 2010, price inflation in US$ on basic fuels varied from 16% to 87%, relative to 2005. During this time, the local currency depreciated by half. As a consequence, the price of charcoal and LPG doubled, while that of fuelwood price tripled, and kerosene quadrupled. The dramatic kerosene price surge was likely due to the removal of the subsidy. As an alternative strategy to stabilize the fuel price hike, the electricity price was reduced by 33%. Notwithstanding the government's efforts and excluding the case of electricity, modern fuel prices are still on the high side. Like electricity, there are other relatively sustainable fuel sources, such as natural gas, that can be commonly found; oils from non-edible plants and ethanol from molasses also bare great potential.

In 2005, 7 GJ of the primary energy yielded 2 GJ of final energy (30% efficiency). Traditional fuel accounting for 75% of the primary energy produced nearly half of the final energy with 20% average efficiency. Meanwhile, modern energy accounting for 25% of the primary energy share produced an equal amount with 60% average efficiency. With 50% average stove efficiency, the amount of sustainably sourced energy needed to replace the 1 GJ end-use energy produced from traditional fuel is 2 GJ. Such fuel substitution could reduce primary energy consumption from 7 GJ to 3 GJ. Since 2007, ethanol production from molasses by the sugar industries has reached close to two-hundred million liters. Half of it is mixed with gasoline for use in transportation. The remaining hundred million liters is sufficient to meet half of the primary energy (1.5 GJ per person per year) needed to meet household needs. In 2005, electricity met nearly 1 GJ of the primary energy. Between 2001 and 2007, electricity production doubled, and in the next five years when the millennium dam with 10,000 MW capacity is completed, electricity could supply the remaining 1.5 GJ per capita needed. Therefore, electricity from hydropower and ethanol from sugar byproduct could meet the sustainable household energy needs of Addis Ababa.

The price inflation of kerosene in 2005 relative to 1995 even with the subsidy was 87%. In 2010 relative to 2005, it was more than 250%. If ethanol is sold at the current price of electricity, the cost of energy for the 3 GJ per capita primary energy required to produce 2 GJ of final household energy per capita could go as low as $15 per person per year. Such fuel substitutions therefore could reduce the household energy expenditure by half relative to 2005.

4. Conclusions and Recommendations

Traditional household energy sources are renewable, but the rate of consumption is much greater than the rate of production. Furthermore, the efficiency of the stoves used to process these sources is very low. Evidently, traditional energy is not sustainable. Traditional energy use increases the rate of deforestation and land degradation, which in turn can lead to excess soil erosion and loss of soil fertility. This further contributes to the decline of agricultural productivity and production, perpetuating the vicious cycle of rural poverty. Indoor air pollution associated with kerosene and traditional fuel use is a major health concern, especially for women and children. Globally, two million people die prematurely as a result of indoor air pollution associated with the inefficient burning of biomass. Chronic obstructive respiratory disease resulting from indoor air pollution kills one million people each year. Particulate matter inhaled from indoor air pollution is the cause of 50% of pneumonia deaths among children under the age of five (WHO, 2006).

Households in Addis Ababa consume more than half a million tonnes of wood in the form of fuelwood and charcoal, as well as about a hundred thousand tonnes of animal manure. Doing away with traditional fuels, therefore, would save more than fifty thousand hectares of forest per annum, help recycle soil nutrients more effectively, and minimize deforestation and land degradation. As such, this triple-win scenario could contribute to an increase in agriculture productivity, helping to break the cycle of rural poverty while also combatting global climate change.

During the decade of study (1995 – 2005), traditional fuel consumptions in Addis Ababa increased by about 10%. At the same time, modern fuel consumption increased by 50%. The overall trend is positive, but in addition to electricity, other relatively sustainable fuels such as ethanol could still be promoted. Substituting kerosene with sustainable fuels would reduce indoor emission and, at the same time, save the nation more than twenty five million USD per annum, which would help reduce the trade deficit.

In Ethiopia, fuel and electricity are owned by public enterprises. The demand side, however, is lagging behind and failing to make full use of the available sustainable fuel supplies. The government, therefore, should enter into partnerships with private sector companies to effectively complete the value chain. With such Public-Private-Partnerships, the nature of energy use and production in Addis Ababa has the potential to be transformed quickly for the benefit of local residents as well as the global environment.

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